A Mesoscale Analysis of the Impact of Snowpack on Climate Variability in the Sierra Nevada Region

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RESEARCH OBJECTIVE

Greater than 70% of the annual streamflow in the western United States is derived from snowpack. Hence, accurately forecasting snowpack is essential to this region's economy and well-being, and numerical models are necessary (and powerful) tools for this purpose. The objectives of this study were to evaluate the snow scheme with an advanced mesoscale model, using observational evidence, and to investigate the impact of snowpack on climate variability in the Sierra Nevada region.

APPROACH

The model used is the fifth-generation Mesoscale Model (MM5) developed by the Pennsylvania State University/National Center for Atmospheric Research. This model was used to generate 12 km resolution results that account for complex topography in the Sierra Nevada. The observed Snow Water Equivalent (SWE) depths for this region were assimilated into MM5 to allow for an investigation into snow evolution and its related processes. This investigation was an approach toward correcting the identified model deficiencies caused in part by the simple snow physics in the land-surface model coupled to MM5. The observed daily SWEs were measured through the automated Snowpack Telemetry system during the snowmelt season from April 1998 to June 1998.

ACCOMPLISHMENTS

Comparison of observed and simulated SWEs (Figure 1a) indicates that at the 12 km resolution, MM5 poorly represents the snowpack over the Sierra Nevada region during the snowmelt season. At the same time, with the misrepresented snowpack, the model produces a strong warm bias at the near surface (Figure 1b) and exaggerated precipitation (Figure 1c). Subsequently, the observed SWEs (red line in Figure 1a) were incorporated into the model to improve its climate-simulation performance. After the SWE assimilation, the simulated 2 m height air temperature was in very good agreement with observations. In the model, because the assimilated SWE consumes a large amount of energy on account of the melting process, the surface skin temperature was reduced, which decreases the upward sensible heat flux. The decreased sensible heat flux supplied less energy to the near surface air and alleviated the warm bias in the 2 m height air temperature. Furthermore, SWE assimilation caused a lowered sensible heat flux as well as a colder surface, leading to weaker outgoing long-wave radiation, reduced air temperature in the lower troposphere, and a stabilizing of the atmosphere. The more stable atmosphere restricted atmospheric convections and thus decreased the amplified precipitation.

SIGNIFICANCE OF FINDINGS

This study (Jin and Miller, 2003) indicates that snowpack has a significant effect on near-surface air and precipitation over the Sierra Nevada. Our findings provide a substantial advancement in our understanding of climate variability in the Sierra Nevada region, as well as direction for future model development.

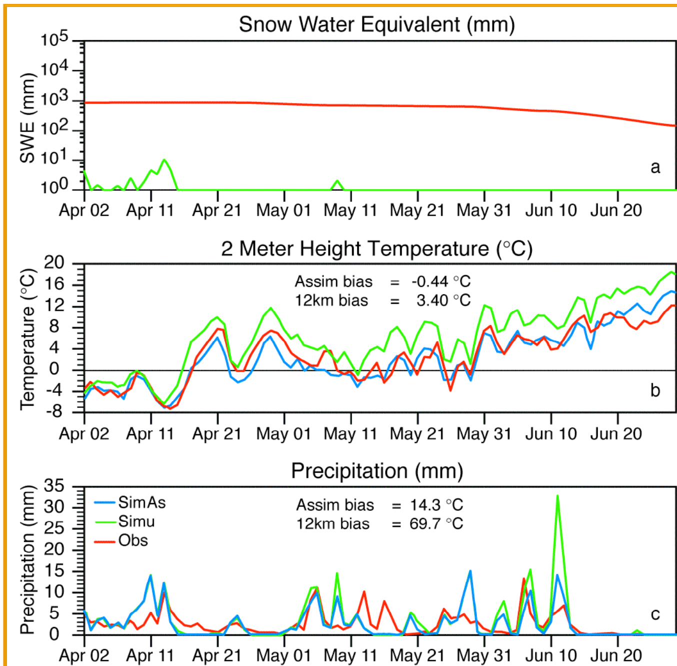

Figure 1. Comparison of simulations and observations averaged over the Sierra Nevada region for the period of April 2–June 30, 1998: (a) Snow water equivalent (mm); (b) 2 m height air temperature (ºC); (c) Precipitation (mm). Obs is observations, Simu is the 12 km resolution simulation with no SWE assimilation, and SimuAs is the 12 km resolution simulation with SWE assimilation.

RELATED PUBLICATIONS

Jin, J., and N.L. Miller, A mesoscale analysis of snowpack on climate variability and snowmelt mechanisms in the Sierra Nevada Region. Presented at the PACLIM Conference, April 2003, Pacific Grove, California; J. Hydrometeorology, September, 2003 (submitted).

Jin, J., and N.L. Miller, An analysis of climate variability and snowmelt mechanisms in mountainous regions. J. Hydrometeorology, September, 2003 (submitted).

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